Cloud Radiation Convective Feedbacks Inferred from the A-Train

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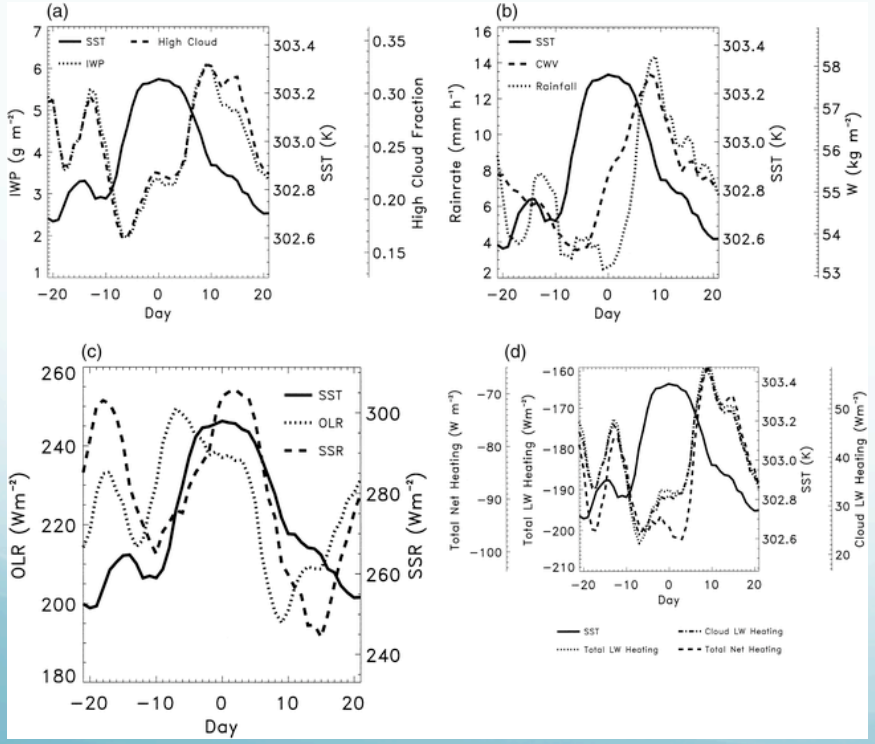
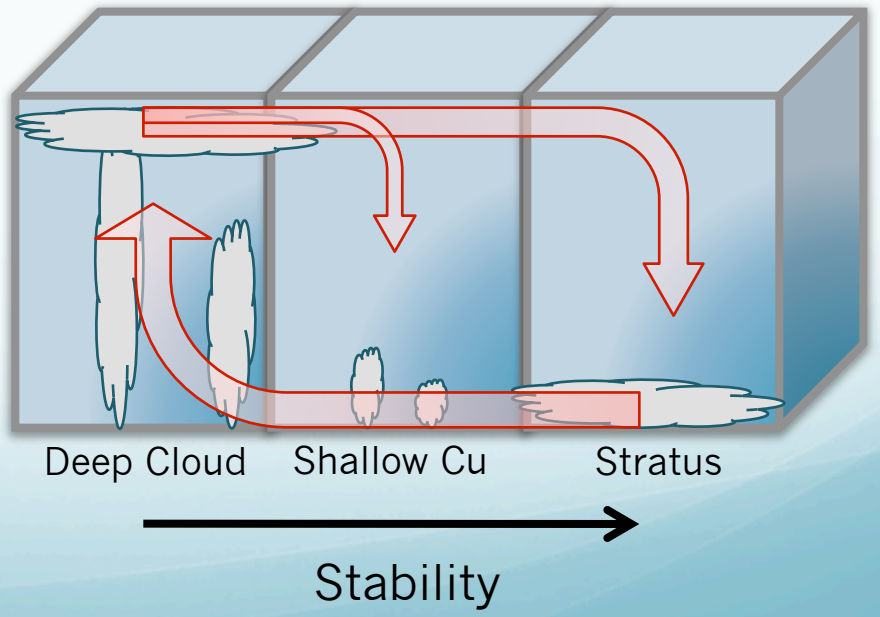
Motivation

$$-R'_{atm} \approx LP'$$



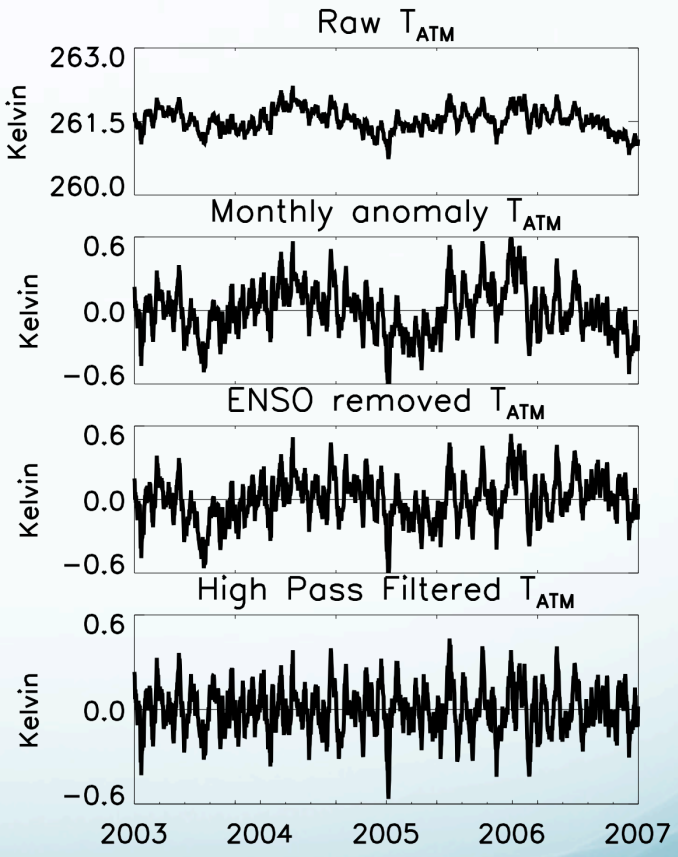


Purpose

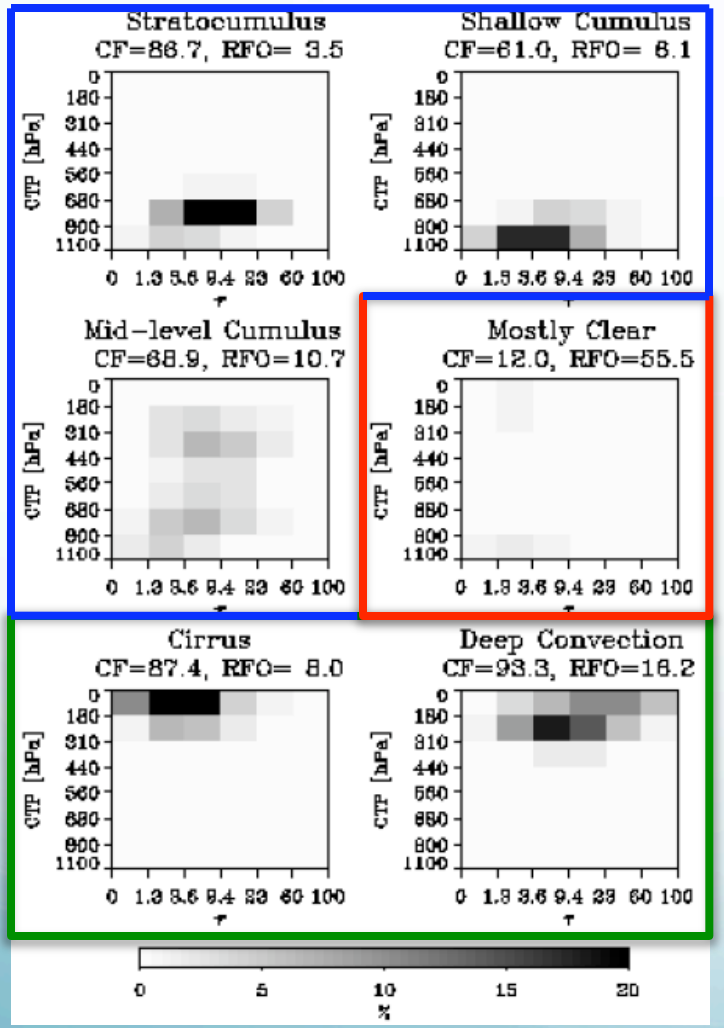
- Examine large-scale correlations between tropical precipitation (latent heating) and radiative heating.
- Instruments
  - CERES => Radiative Fluxes
  - AMSR-E => Precipitation
  - MODIS => Clouds
  - AIRS => Temperature
- Time period => 2003-2007
- Domain => tropical oceans [30N-30S]

Methodology I: Time Series Filtering

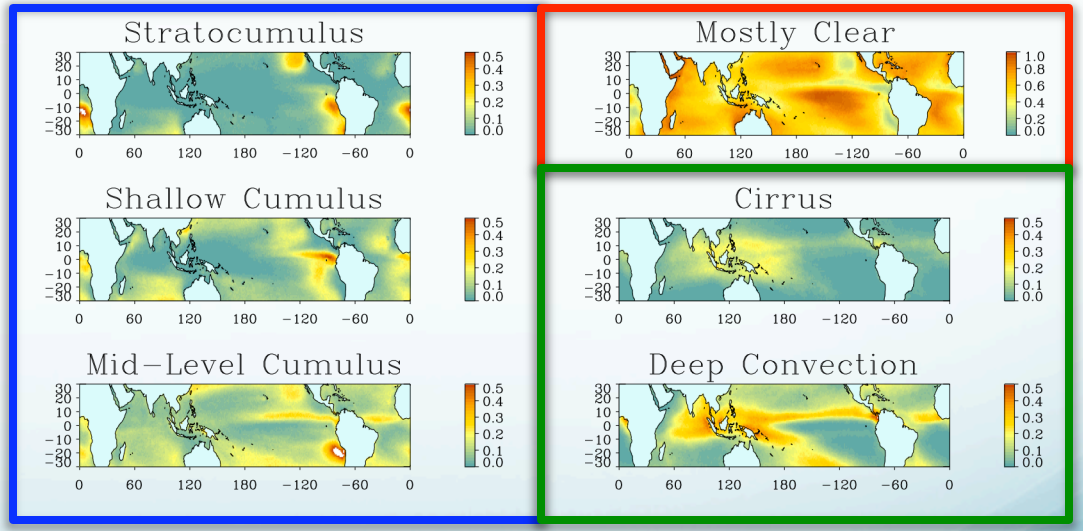
1. Create 3-day tropical means
2. Remove seasonal cycle
3. Apply high pass filter (120 day)
   - Time series of high frequency components of the large-scale mean



Methodology II: Cloud Clusters



Shallow
Clear Sky
High Cloud

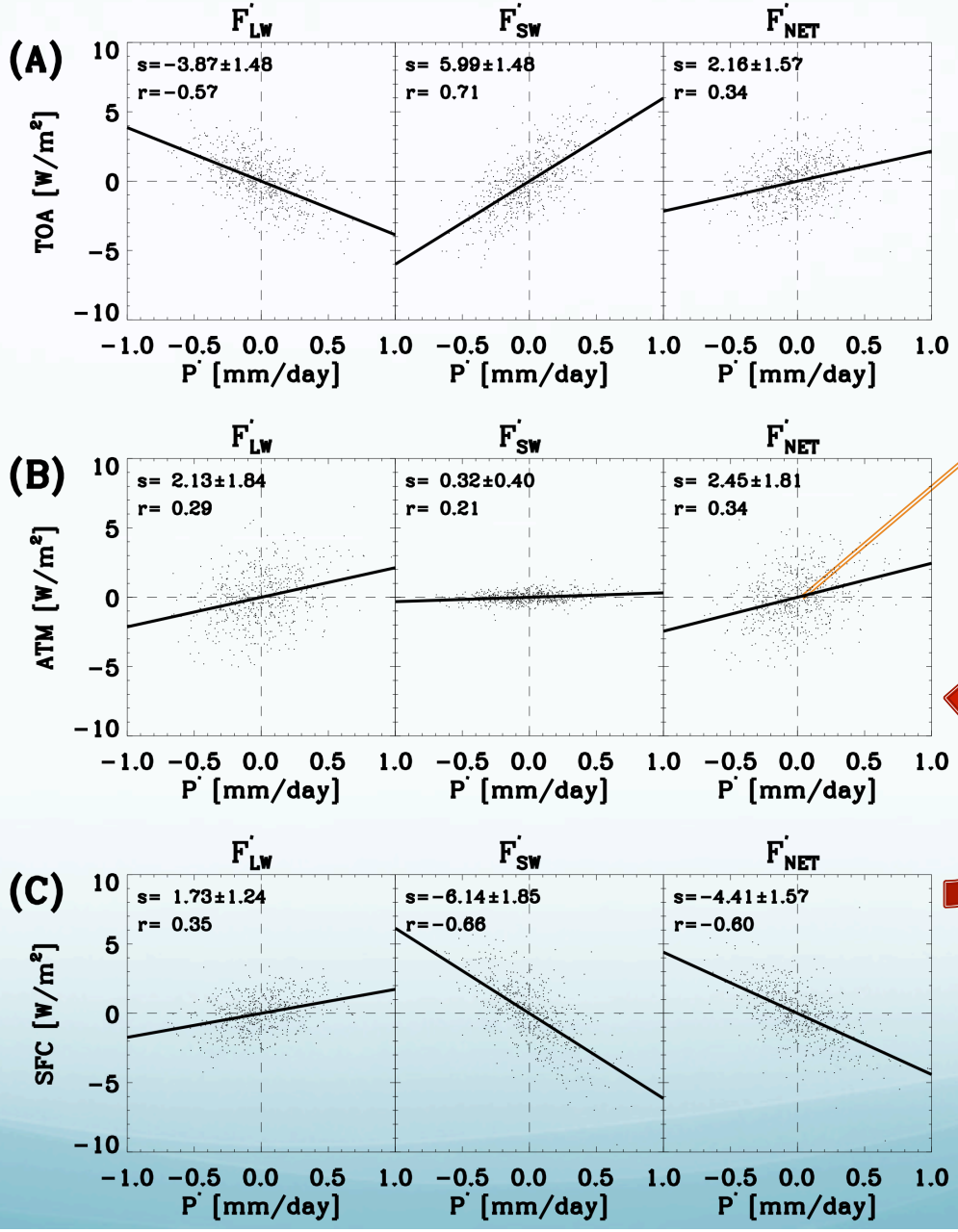


Precipitation-Radiation Relationships

Shortwave and longwave cancel

Longwave heating

Shortwave cooling



$R'_{atm} \sim 10\%$ LP'

Perturbation budget Analysis

$$P_i = \sum_j a_{i,j} P_{i,j}$$

$$P'_i = \sum_j \overline{a}_j P'_{i,j} + \sum_j a'_{i,j} \overline{P}_j$$

Similarily for any variable

$$x'_i = \sum_j \overline{a}_j x'_{i,j} + \sum_j a'_{i,j} \overline{x}_j$$

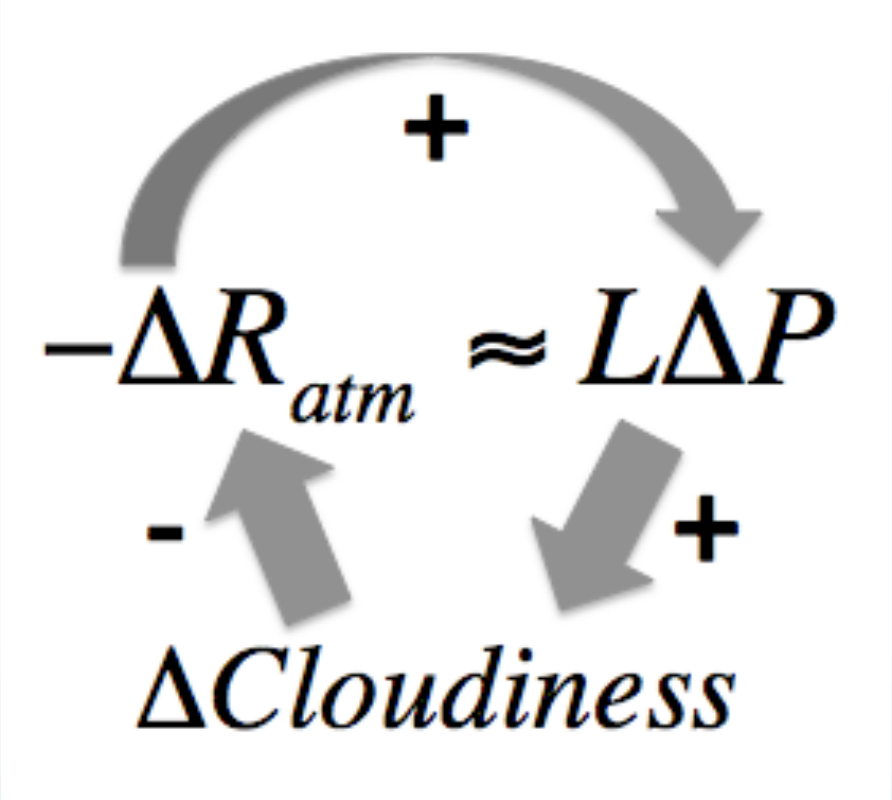
$$x'_i \approx \beta_1 \sum_j \overline{a}_j P'_{i,j} + \beta_2 \sum_j a'_{i,j} \overline{P}_j$$

	P'	SW'_{TOA}	LW'_{TOA}	CF'	CTT'	τ'
Intra-cluster term $\sum_j \overline{a}_j P'_{i,j}$	62.9%	9.2%	0.6%	2.3%	1.1%	25.5%
cluster RFO term $\sum_j a'_{i,j} \overline{P}_j$	36.4%	59.3%	70.5%	53.1%	55.3%	20.0%

Variability explained in the TOA anomalies by the fractional occurrence of each cluster

	SW'_{TOA}	LW'_{TOA}
Stratocumulus	10.1%	1.8%
Shallow Cumulus	2.1%	4.0%
Mid-Level Cumulus	15.4%	0.6%
Mostly Clear	78.5%	27.3%
Deep Convective	18.4%	30.1%
Cirrus	46.6%	71.2%

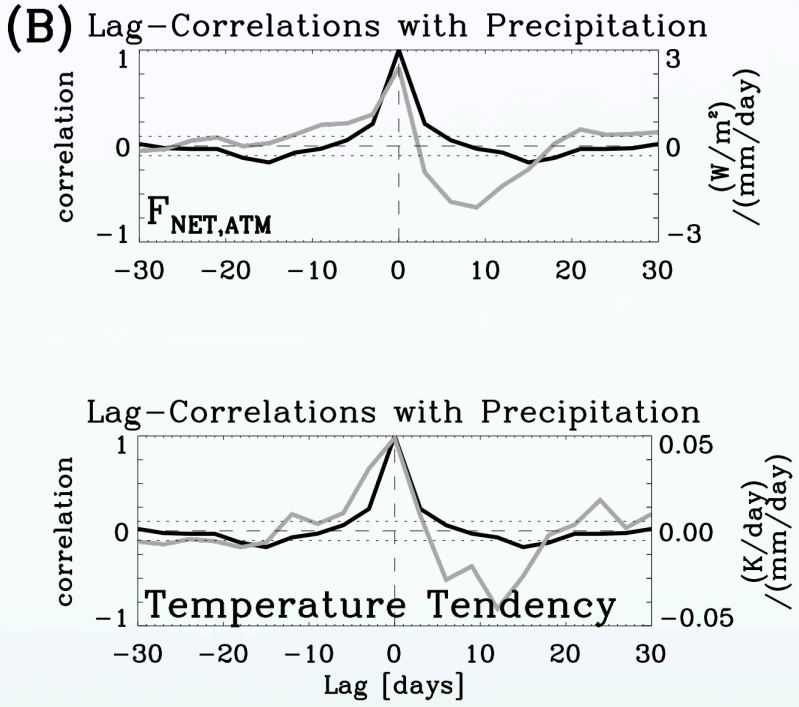
The Feedback



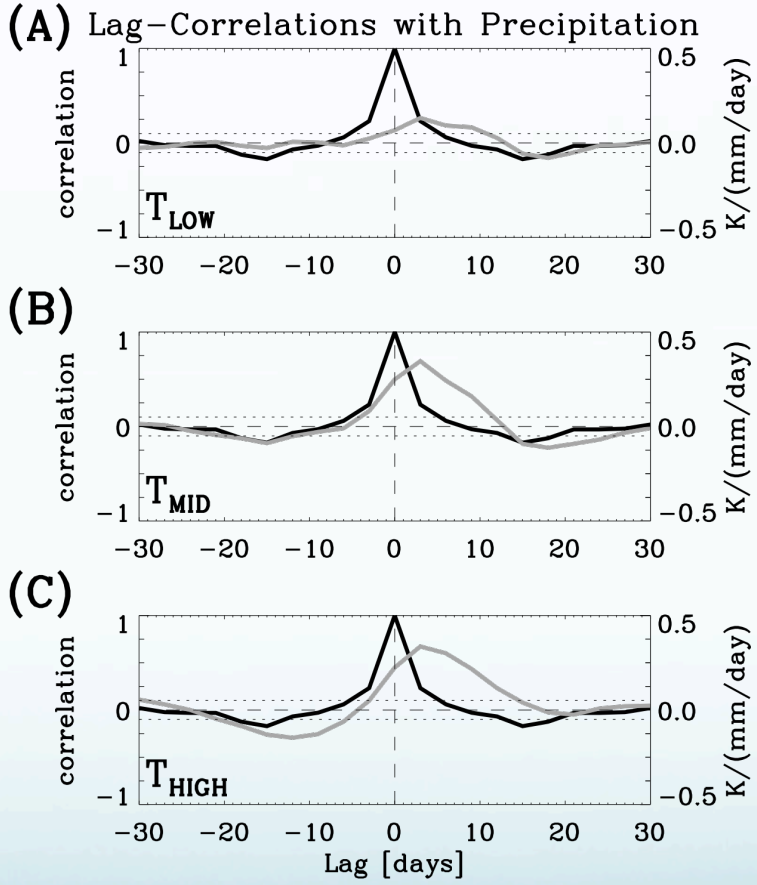
Acts on the large scale tropical mean!

$R'_{atm} \sim 10\%$ LP'

Temperature-tendency lag



Temperature lag



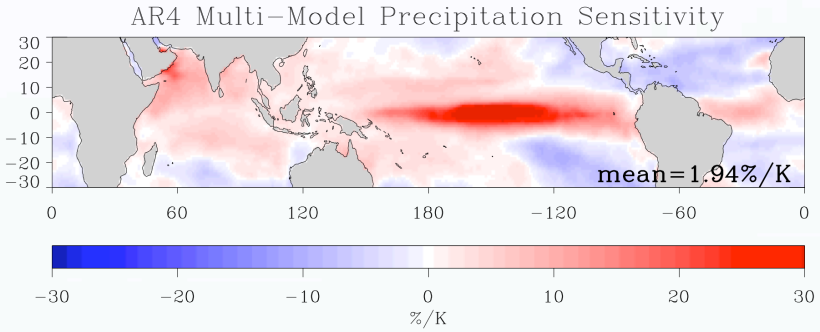
Unstable → Stable

Summary

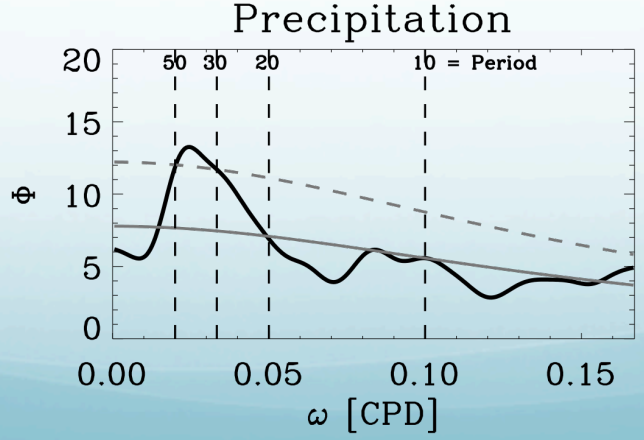
- A negative radiative-convective cloud feedback is observed in the tropical atmosphere on intra-seasonal time scales.
  - Feedback strength ~ 10% of the latent heating.
  - Dominated by fractional area of cirrus and clear sky.
  - Acts on large spatial scales.

Open Questions

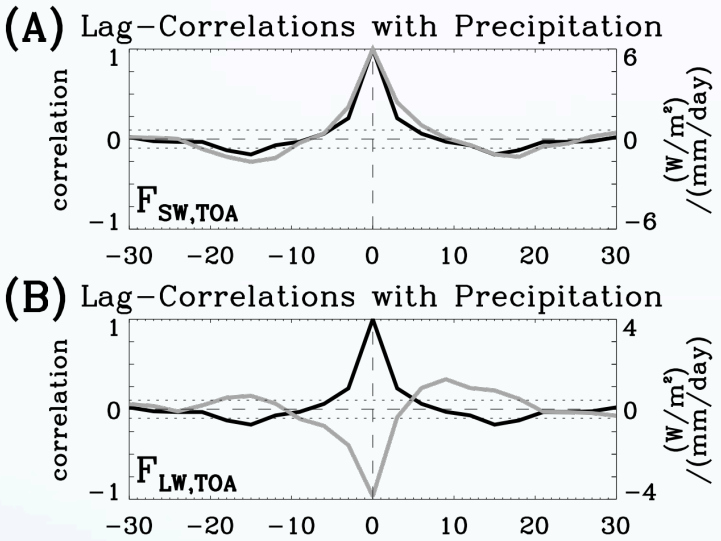
- How do these relationships scale up to time scales relevant to climate?

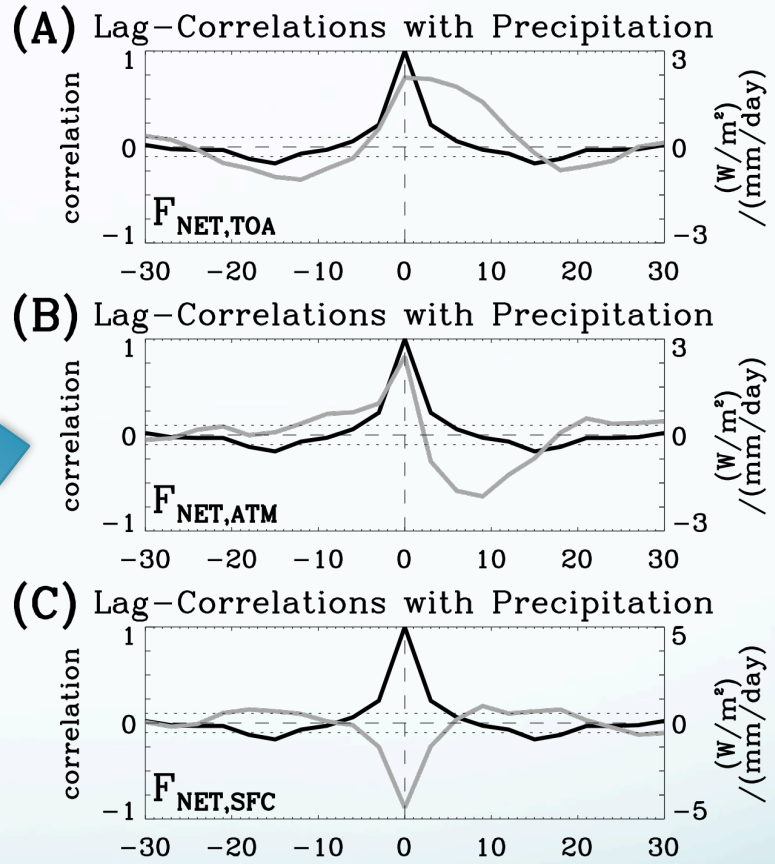


- Does this feedback influence the time-scale of the intra-seasonal oscillation?



Radiation-lag



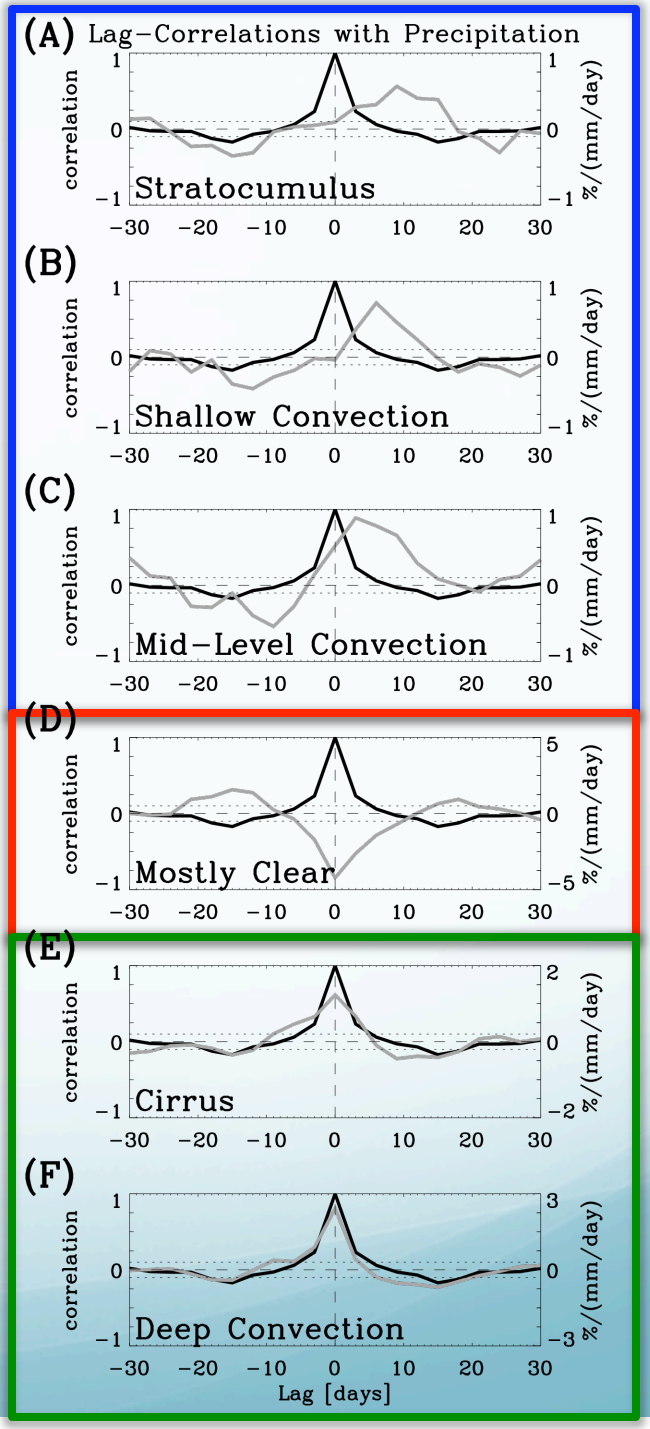


At the TOA: shortwave and longwave tend to cancel

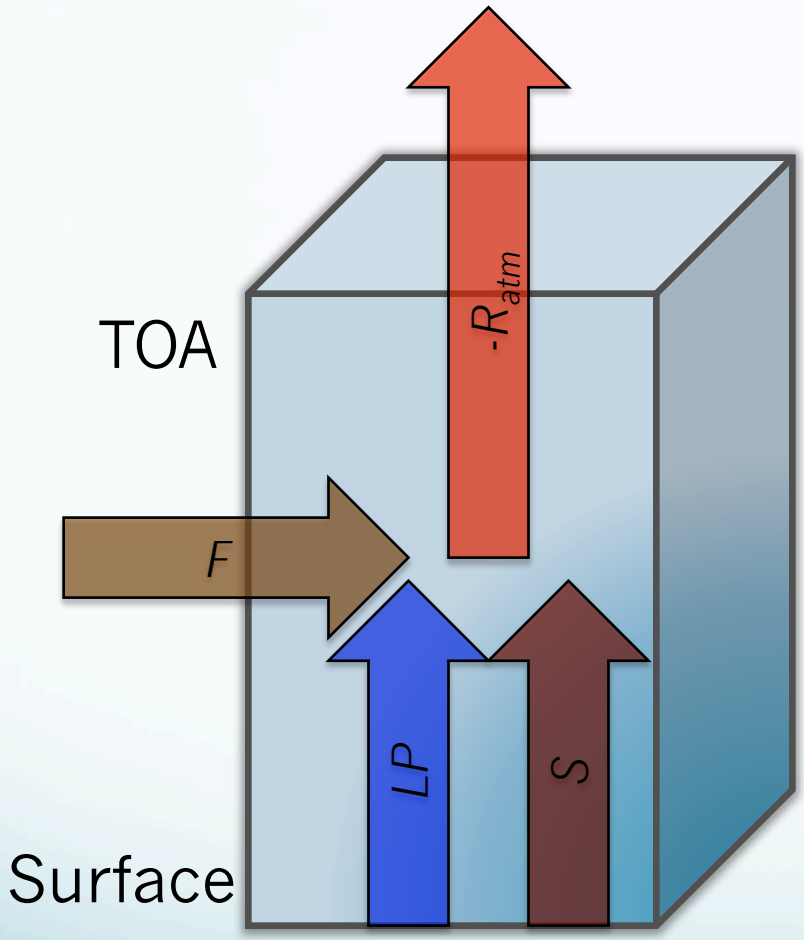
Can we explain heating asymmetry?

Cloud-Cluster lag

Shallow
Clear Sky
High Cloud



Radiative-Convective Energetics



$$-R'_{atm} \approx LP'$$

The radiation anomaly scales with the precipitation anomaly

$$-R_{atm} = LP + S + F$$

Approximation